THE SUBJUGATION OF THE MISSISSIPPI.

THE Mississippi River Commission was created by Act of Congress, approved June 28, 1879. It consists of seven members, appointed by the President, of whom three are required to be from the Engineer Corps of the Army, one from the Coast and Geodetic Survey, and three from civil life, of whom two shall be civil engineers. It is provided in the act that the commission shall—

> Take into consideration and mature such plan or plans and estimates as will correct, permanently locate, and deepen the channel and protect the banks of the Mississippi River; improve and give safety and ease to the navigation thereof, prevent destructive floods, and promote and facilitate commerce, trade, and the postal service.

The commission was duly organized, and, after consideration of the subject, reported a plan of improvement, which has been adopted by Congress, and for the execution of which an appropriation of $1,000,000 was made by Act of March 3, 1881, and another of $4,123,000 by Act of August 2, 1882, all to be expended below Cairo. Under these appropriations the work is now in progress, its execution being in the hands of officers of the Engineer Corps detailed for that purpose by the Chief of Engineers. Its completion, according to the plans proposed, will require a number of years, and further large appropriations. There is, therefore, added to the interest which belongs to the subject as a great engineering problem, that which attaches to every object of public expenditure.

It is the purpose of this article to set forth briefly the general plan proposed by the commission, and the reasons upon which it rests. In order to a clear apprehension of the questions involved, a short description of the river in its unimproved condition will be useful.

At the city of Cairo, upon the southern extremity of the State of Illinois, are gathered together the waters of five great rivers, viz: the Missouri, the Upper Mississippi, the Ohio, the Cumberland, and the Tennessee. Between that point and the Gulf of Mexico lies the Mississippi River proper, 1,097 miles in length as it flows. Its course is through an alluvial plain, six hundred miles long and from twenty-five to eighty miles wide. In this basin is embraced an area of 41,000 square miles, of which 32,000 square miles are liable to overflow. Borings made at eighty-three places between Cairo and Vicksburg show one hundred and thirty-one feet mean depth of alluvial soil. From Cairo to the mouth of the Red, the width of the river between banks varies from 1,900 to 13,800 feet, the mean being 4,400 feet. Below the Red the width rarely exceeds 3,500 feet, the mean being 3,350. Between Cairo and Memphis its least depth at low water is five feet; between Memphis and Red River, six feet; and between Red River and New Orleans, fifteen feet. The variation in its discharge is enormous, passing from 100,000 cubic feet per second at low water to 1,600,000 at the highest flood. The range between high and low water mark at Cairo is fifty-two feet; at Memphis, thirty-five feet; at Vicksburg, fifty-two feet; and at New Orleans, fourteen feet. In its greatest floods its water surface stretches from hill to hill, across the entire valley; at extreme low water, it flows between banks from thirty to forty feet high. The depth of its inundation bears no comparison with its area, being, on an average, less than three feet over the arable lands. In the swamps it is much more. Its flood elevation at Cairo is three hundred and twenty-two feet above the sea. Its fall from Cairo to Memphis is about six inches to the mile. Thence to the gulf its fall steadily diminishes, being about one and a half inches per mile at New Orleans. It is one of the muddiest rivers in the world. The greater portion of the sediment received by it at Cairo comes from the Missouri, but this supply is constantly reinforced by the caving of its own banks, which are washed into the river at an estimated rate of 5,000 acres per annum.

All plans for the improvement of the Mississippi that have been prominently discussed rest upon one of two theories: one, that the remedy for the evils existing consists, essentially, in the concentration of the water of the river and the equalization of its flow; the other, that it consists in the subdivision and

diffusion of its volume. The former theory is the one held by the commission and adopted by Congress, though the other has advocates, whose views continue to be urged in Congress and through the press.

There are numerous opportunities to let out of the channel of the Mississippi large portions of its water. The Atchafalaya, which receives its waters from the Red River, at a point only six miles distant from the junction of that river with the Mississippi, is there several feet lower than the Mississippi. At the present time the water of the Red rarely reaches the Mississippi at all, but, for the most part, flows down the Atchafalaya, augmented by a large outflow from the Mississippi. It is only when the Red is high and the Mississippi low, that there is any flow from the former to the latter. The difference of level between the Mississippi and the Atchafalaya increases as they descend, so that at Plaquemine the difference is twenty-two feet, and the distance between them eleven miles. On the east bank, at Bonnet Carré, the difference of level between the river and Lake Pontchartrain is twenty feet, and the distance between them five miles. At Lake Borgne the difference of level is fourteen feet and the distance six miles. So that it is quite possible to make outlets by which the flood-water, or, for that matter, all the water of the Mississippi, could find its way to the gulf by shorter lines and lower levels than those of the present river. And when men stand appalled at the sight of its devastating floods, the suggestion of quick relief by outlets seems at first sight so practicable and reasonable that it is not strange that it should find favor in many minds.

The reasons which lie against this theory require some thought for their clear apprehension, but rest, as is believed, on well ascertained laws.

The three most difficult factors in the problem are, the wide variation in the volume of the river's discharge, the quantity of solid matter transported by its current, and the softness of its banks. If any one of these three elements were absent, the questions presented would be comparatively simple.

To contain the river at its flood requires a great channel. Its banks are so friable that its constant tendency is to make itself room by tearing them down. When the flood subsides the material of which they were composed is found scattered over the broad channel in obstructing bars and shoals. Over and

among these the low-water river has to make its way by such tortuousand changing path as it can find or make for itself. It is then that navigation becomes difficult and dangerous. There is water enough in the river at its lowest stage to furnish ample depth for navigation, if it were confined in a channel of suitable width; and it would make and maintain such a channel for itself if it were not for the interference of the floods.

The problem of the river's improvement comprehends, therefore, in its broadest sense, these two requisites—a high-water channel capacious enough to contain its floods, and a low-water channel narrow enough to afford the depth necessary for navigation. And the more nearly identical in location these can be made, the more permanent and perfect will be the improvement attained.

In the consideration of any plan for the accomplishment of these ends, it is to be remembered that there are very rigid limits to the possibilities of engineering methods applicable to the case. To build upon a foundation of bottomless alluvium any breakwater or training-wall of stone or timber, that shall withstand the floods that pour down from the north like an ocean let loose, is impossible. To dig and keep open a channel for a river that flings down in its own pathway a sand-bar a mile square as though it were a handful of ashes, is equally impossible. Hence, if at any point a deeper channel is needed, the river must be compelled to dig it; if a new bank is needed, the river must be coaxed to build it. Its own Titanic hands are the only instruments equal to either task.

If any one will set a tumblerful of the coffee-colored water of the Mississippi where it will remain undisturbed for twenty-four hours, he will find, at the end of that time, a teaspoonful of mud in the bottom of the tumbler, while the water will be comparatively clear. If he had kept the water in motion all the time he would have found it as turbid as when he took it from the river, and no deposit at the bottom. In this tiny experiment is illustrated the most important law of the Mississippi River's life, viz.: that the power of water to sustain and transport sediment depends upon its motion. The exact relation between the velocity of moving water and its silt-carrying power is not ascertained. It varies with the size and specific gravity of the particles. But enough is known to warrant the general statement that every diminution of the velocity of a running stream dimin-

ishes its silt-transporting capacity. It is not necessary, in order to produce this result, that there shall be a cessation of motion in the water; a diminution of its rate is sufficient.

The operation of this law is universal and invariable, on the largest scale and on the smallest. The miniature torrent that sweeps down the plowed furrow in a hill-side field scours its bed clean as long as it maintains its headlong velocity. But when it slackens its course at the foot of the slope, it throws down its load of sand and loam in an instant. The delta which forms at the mouth of every sediment-bearing river is the same phenomenon on a larger scale.

Upon the Mississippi River the traveler is never for a moment out of sight of visible evidence of the operation of this law. The following examples will be familiar to any one who has been upon it. In the outer curve of every bend, where the current is swift and strong, the channel is deep and clean. On the inner side of the return curve there is slack water and a bar. Wherever the channel is narrow and deep, there is a high velocity and no deposit of sediment. Where it is excessively broad and shallow, bars accumulate rapidly.

At a bank full stage the river has a rapid current and is heavily loaded with sediment. At the overflow stage the water escaping laterally over the banks is suddenly checked in its velocity, and immediately begins to drop its load, leaving a diminishing deposit as it recedes. To this layer the next flood adds another, each being thickest at the margin next the river, where the escaping water experiences the first diminution of its velocity. In this way the river builds up its own banks by overflow; and in consequence of this method of building them they are highest nearest the river, the receding declination sometimes reaching twelve feet in a mile, and being rarely less than five.

Following the course of great overflows through the forests adjacent to the river, the observer will find on the farther side of trees, logs, and other obstructions, sand reefs and areas of deposit marking every place where the advancing water was checked in its velocity.

It occasionally happens that the river cuts off a long bend by a short channel across its neck, leaving a horseshoe-shaped section of the old channel unused. At the open ends of this abandoned channel the water in it mingles with the current flowing past, and so has a gentle inward and outward flow as the

river rises and falls. The consequence is a deposit of sediment at the entrances of the abandoned channel, by which they are ultimately filled up and cut off entirely from the new channel, forming deep, clear, crescent-shaped lakes. There are many such lakes in the valley, some of them now several miles from the river. Such a cut-off occurred at a bend opposite Vicksburg in 1876, leaving the city upon one arm of the abandoned bend. The lower end of that arm is already filled up to the height of twenty-five feet above low water, and fifty feet above the old bottom, leaving the city's wharves and elevators a mile and a half inland at ordinary and low stages.

By shiftings of the channel, the formation of islands, and other causes, the subsidiary channels, called chutes, are formed in large number. If a swift current set through a chute, it enlarges; if a sluggish current flow through it, it fills with sediment. Sloughs and outlets leading out of the river into the swamps, in which the free flow of water is obstructed by willows, are often permanently closed in the same manner.

As the river elongates its bends by caving off the outer bank, there is commonly formed a sloping bar on the inner bank, which advances as the outer bank recedes. As fast as this bar rises above ordinary low water, it is covered by a growth of willows. At high stages, the water flowing over the bar is obstructed by this growth, and successive deposits of sediment are thus caused, which ultimately build the bar up to the full height of the adjacent banks. By this process the river shifts its channel, tearing down one bank and building up the other as it goes.

Some of the methods of channel improvement now in use have been copied from the processes of nature just described. When it is sought to narrow an excessively wide channel, permeable screens, made of piles and interwoven brush or poles, are set on the bar where it is desired to form new banks, at intervals of a thousand feet or less. The water, in flowing through these screens, loses so much of its velocity that it drops its sediment very rapidly after passing them. The effect produced by such structures is sometimes quite remarkable. In favorable localities a fill of forty feet in depth has resulted in a single season. At Horsetail Bar, below St. Louis, may be seen an area of more than a thousand acres of land, which has been built up from the river-bed to an average depth of twenty-five feet by the means

just described. A mere line of piles, eight feet apart, will often produce a heavy deposit below them.

These numerous examples have been cited in order to illustrate and enforce the proposition stated at the outset: that the greatest law of the river's life is that it shall be forever laden with a burden which slips from its grasp the instant it loiters by the way. The whole valley is itself the result and the proof of the existence and the operation of this law. There is not a shovelful of earth in all its square miles that has not been dissolved in water, and carried by water to the point where its journey ended, for want of velocity to carry it farther. Every grain of sand, every drop of water, every inch of movement, every low stage, every high stage, every flood, is equally obedient to the same great law. The engineer who has learned its meaning well has taken the first step toward a successful solution of the problem of the river's improvement. He who ignores or defies it puts himself in the pathway of forces as irresistible in their operation as the march of a glacier.

This brings us to the practical question. Here are so many cubic miles of water per annum to be conducted to the sea. It is desired to do it in such manner as to afford the best possible low-water navigation, and the least possible high-water inundation. Shall it be confined in its course to one channel, or shall it be subdivided or allowed to subdivide itself into several?

The excavation of a river-channel is work. The transportation of sediment is work. The accomplishment of either involves the expenditure of energy. So that it is but another statement of the same question to say: How will a given quantity of water perform most work—in one concentrated volume, or in subdivisions?

To this inquiry the experience of every person furnishes a ready and true answer. A gentle rain, falling on the earth's surface, leaves its lightest vegetable mold undisturbed. The same quantity of water, descending in a waterspout, tears away its solid hills. The water which trickles over a field through thousands of infinitesimal and broken channels, without producing the least abrasion of its surface, would, if concentrated in one volume on the same surface, plow it deep and wide. There is nothing else in nature of which it is so literally and familiarly true that "in union there is strength," as of

water. Subdivided finely enough, it is the morning mist; concentrated largely enough, it is nature's master mechanic, the continent-builder of the world.

Taking its whole life together, there is, in the phenomena of the Mississippi River, as elsewhere, a perfect correlation of forces. It does all the work it can all the time. It excavates its bed as deep and wide as it can. It carries out of its channel as much of the sediment mixed with its water as it can. When it drops from its broad shoulders a hundred thousand cubic yards of sand on one bar, as it often does, it is because it can carry it no farther. It never drops a spoonful except for the same reason.

All the conditions of the river are the result of its own forces. It has no antecedent banks, bars, width or depth; all these are its own creation. It made yesterday the things that make it to-day; it is making to-day the things that will make it to-morrow. Its present inadequacy to meet the wants of men is the result of its inadequate work in the past. It overflows its banks because its channel is not capacious enough to contain its flood. To make its channel more capacious requires more work. At low water it stumbles over bars which it lacks strength to displace. To remove them requires more work. It makes its shoal places shoaler by the deposit of sediment which it wants energy to carry farther. More work would do it. So that if the river of the future is to subserve the interests of mankind better than the river of the present, the river of to-day must be induced to do more and better work. This is to be accomplished by the conservation, concentration, and wise direction of all its energies. That this means the conservation, concentration, and wise direction of its *volume* seems too obvious to need repetition.

Depletion, or subdivision, is a step in exactly the wrong direction. It is a change toward weakness; not toward strength. An outlet may serve to lower a flood for the time being, but the result is a temporary advantage gained at enormous future cost. The diminution of volume produced by the outlet means diminution of energy. It means a smaller, weaker river from that point to the sea. And that means a river less able to remove bars, less able to excavate a channel, less able to carry sediment, less able to contain a flood.

It is in the nature of things that each portion of the river shall, in its turn, bear the burden of the complications above it. The bars that obstruct it came down from above. The sediment that loads its water came down from above. Hence, there is the clearest necessity that it should, as in the order of nature it does, augment its strength as it descends. An outlet reverses this order of nature and of reason. It diminishes the energy of the river below, without lightening, in any like degree, the burdens cast upon it by the river above.

It is not possible, without accurate and expensive observations and measurements, to trace all the injurious effects of an outlet upon the river below. But enough is visible to common observation to show the unvarying operation of the laws stated. At its mouth the Mississippi has tried the outlet system of its own accord, by subdividing into four distinct channels. From New Orleans down to the widening of the channel, preparatory to its subdivision, it has nowhere less than a hundred feet of depth. In its four subordinate channels the depth rarely exceeds fifty feet; and at the mouths of all, except the one improved by the jetties, it is about sixteen feet. Suppose the same subdivision had taken place two or three hundred miles higher up, would not like results have followed in the channels below?

Outlets in the form of great crevasses have frequently occurred. They are always followed by increased deposits in the bed below them.

Channels conveying unfiltered Mississippi water invariably contract their dimensions to the smallest space that will contain the water flowing through them. The law governing chutes has been stated already;—a swift current keeps them open; a sluggish current fills them up with sediment. When an island appears in the center of the river, it is rare that a good channel is maintained on each side of it. Something will occur to disturb the equilibrium between them: one will begin to rob the other of water: whereupon the other will begin to fill with sediment,—a process which increases in rapidity as the disproportion of flow grows greater.

At the mouth of the Red River is a remarkable illustration of the same law. The Red formerly entered the Mississippi at the apex of a bend. In 1831 the bend was cut off. For a time the Red used the upper arm of the bend as its channel, during which time it rapidly contracted to the dimensions suitable for the

conveyance of the water of the Red River alone; while the lower arm of the bend closed up entirely. Afterward the Red abandoned the upper arm of the bend, and cut a channel just large enough for its own flow through the lower one; whereupon the upper one filled up. Later, the enlargement of the lower Atchafalaya, whose head is in the apex of the old Mississippi bend, near the original mouth of the Red, produced an active outflow from the Mississippi, which has been already described, and, in consequence, the channel is now enlarging. So that, in the space of six miles, between the Mississippi and the head of the Atchafalaya, there have been, within fifty years past, first, a Mississippi channel 3,500 feet wide, and probably sixty feet deep; then a dry bar; then a Red River channel three hundred feet wide and ten feet deep; and now a rapidly growing outlet.

The use of the word "unfiltered" in the general statement above is material, and marks an important distinction. The statement is not true of a channel conveying clear water. The Yazoo River is one of this class. There was formerly, at Yazoo Pass, nearly opposite Helena, an outlet which diverted a large volume of water from the Mississippi into the Yazoo, which that river returned to the Mississippi at Vicksburg. By this means the channel of the Yazoo was excavated deep and wide. The pass was closed a number of years ago. Since then the chief water-supply of the Yazoo has come from the swamp-drains, which discharge clear water, and from Mississippi overflows, which are thoroughly filtered by the woods and swamps through which they travel before reaching it. So that we have to-day in the Yazoo a clear water stream, flowing with slow velocity through a capacious channel which does not perceptibly decrease in size. No such result ever occurs in the case of water charged with sediment.

Nature has made the channel of the Mississippi of increased capacity for discharge as it descends. The permanent diversion of a substantial portion of its water by outlets will reverse that order, and shrink the channel below them to the size required by the diminished river. This shrinkage will take place first by decrease of depth, as the depositing sediment falls to the bottom, and thus the interests of navigation will be the first to suffer. But the mischief will not stop there. When the river and the outlets shall have adjusted themselves to the new conditions created they will, all together, be less able to discharge a great flood than the unimpaired river was alone; and there

will be no place for it to find vent except over the shallow rim of the shrunken channel.

It is not within the purpose of this article to describe in detail the methods by which it is proposed to execute the general plan of improvement recommended by the Mississippi River Commission. Suffice it to say that the retention of the river's water in one undivided volume is the cardinal principle of the plan; and that it is proposed to seek this end by such means as will introduce the fewest artificial conditions into the river's life, and apply most economically and effectually its own forces to the work of improving its own channel. These consist chiefly in the closing of chutes and outlets; the contraction of the channel in places where it is excessively wide, by the creation of new banks from deposited sediment; and the revetment of banks where caving is exceptionally rapid and injurious.

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